APPLICATIONS AND PERFORMANCE OF IR HELMETCAMS

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ABSTRACT

The maturing commercialization of uncooled focal plane arrays and high-density electronics enables lightweight, low cost, small camera packages that can be integrated with headgear. It is only recently that low weight, staring LWIR sensors have become available in uncooled formats at sensitivities that provide enough information for useful man-portable wearable applications. By placing the IR camera on the head, a hands-free infrared virtual reality is presented to the user. This paper describes three helmet mounted IR sensors, presents images from the first-version helmetcam and discusses applications.

1.0 INTRODUCTION

Traditionally, infrared cameras or viewers were handheld, tripod mounted or located in a gimbal. However, with the advent of uncooled arrays, bright displays and wearable computers, the versatility of infrared viewing can now be closely integrated with the user. Three versions of helmetcams have been developed in which the user wears the infrared sensor rather than holds or controls it. This results in an “Infrared Virtual Reality” for the wearer resulting in true and ergonomic infrared vision.

The sensor is pointed by the most natural and intuitive manner—head movements. Human evolution resulted in locating key biological sensor receptors on the head. The eyes and nose are located in front of the head pointing forward. The ears are on the side, but oriented such that they have maximum sensitivity in the region where the eyes are pointed. Even a person's cheeks have a heightened sense of temperature and tactile feel. Thus, they are located in such a manner that the head is to be pointed toward the area where the person wishes the maximum awareness. For example, your head is pointed towards the words that you are reading and if there were a loud noise to the right, you would naturally turn your heard to the right. By integrating the camera and display on the human head, the user can exploit natural movements and reactions to increase situational awareness and personal safety.

Three helmetcams are described: a large (F#0.8 optics) highly sensitive militarized version, a smaller (F#1.3) military version and a specific version designed for firefighters. The described helmetcams are designed to present

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the user with critical symbology and high quality images without constant attention to controls (e.g., auto-non-uniformity correction and auto-focus are provided on some versions). This allows the user to concentrate on the application rather than IR technology. Another important feature is the “Instant On” capability. Because there is no cryocooler, the camera can provide an image within a couple of seconds of being turned-on. This is very important in public safety and military uses where seconds are critical.

2.0 APPLICATIONS

Type of Helmet	Applications
Police Helmet	Generic night vision Detection of polluting cars Evidence gathering (e.g. documentation of a hot engine) Prison control (e.g., cut electricity and control prisoners in the dark) Detection of shallow graves Concealed weapon detection Detection of buried weapons Buried bomb detection
Fireman’s Helmet	Generic night vision Hot spot detection (smoldering objects) Verification that fire is out Potential for backdraft detection Vision through smoke Incipient chemical fire detection Location of victims under debris Location of bodies
Military helmet	Generic night vision Mine detection Search & rescue Targeting Surveillance MOUT Operations
Hard Hat	Generic night vision Hands-free power line inspection Process inspection & control Wildlife monitoring in darkness Forest fire detection Location of underground lines & pipes Archeology Location of clogs in plumbing Mine Safety
Surgeon’s Headgear	Locate veins to avoid when cutting Tumor location Burn Diagnostics

Table 1. Potential Applications of LWIR Helmetcams

There are numerous applications for generic hands-free infrared imaging, some of which are listed in Table 1. Today, the largest group of users for wearable infrared sensors is firefighters. The most critical reason for firefighters to use wearable infrared cameras is to provide vision through smoke and other aersol obscurants. IR cameras provide them with hands-free operation for maneuvering which can increase safety and reduce search and rescue time. Also, observing heated structure in a fire is also important as it gives the firefighter clues to potential hazards such as backdrafts and flashovers.

Police need a tool on their person (as opposed to their car) to conduct a foot-search for a suspect hiding in foliage or using the cover of night. The instant availability, silent operation and high quality imagery of uncooled infrared helmetcams are critical for police forces. Moreover, by combining the infrared with ground penetrating radar, the police can have a handy tool to search for buried weapons, evidence or body parts.

Many potential military applications of wearable sensors relate to enhanced effectiveness in new military venues, such as urban warfare and low intensity conflicts. By mounting a hands-free, control-free camera on a helmet, the soldier can maneuver unencumbered at night even in the presence of occasional bright lights (such as a vehicle’s headlights) as IR sensors do not bloom when viewing visible lights. A wearable infrared sensor will facilitate military search and rescue operations, especially in buildings (urban conflicts). Also, the described sensor can easily be attached to a processor and additional sensors to detect land mines as shown in figure 1.

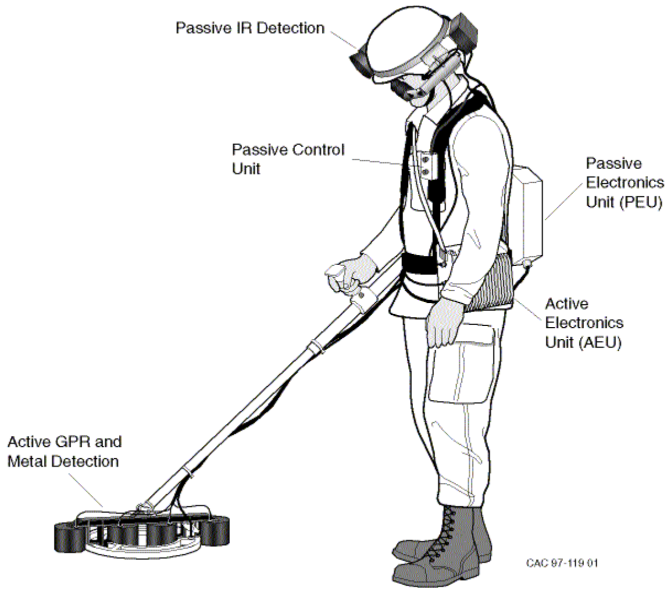

Figure 1. Helemetcam as Part of a Multi-sensor Mine Detection System

3.0 F#0.8 HELMETCAM HARDWARE DESCRIPTION

3.1 GENERAL DESCRIPTION

As shown in figure 2, an infrared helmetcam has been developed and several have been delivered. Table 2 lists some key attributes of this existing militarized camera. They have completed government field-testing with no failures or conditions of overheating (including at Yuma, Arizona in July).

The camera is designed as headgear. Therefore extreme effort is being expended to make it as balanced, small, lightweight and consume as low power as technology permits. Additionally, consideration of ergonomic issues such as including automated features are implicit in the design.

To reduce the weight on the helmet, the batteries and power supply are located in a small backpack, which can be contained in a standard issue load-bearing vest. Additionally a parallel processor can be co-located in the

Figure 2. Wearing The Described Helmetcam

pack to provide high level image processing including an automatic target detection system. The camera includes miniaturized electronics, which output differential digital video and display drivers.

The telescope employs a small three-element assembly with automated active focus and an uncooled FPA. The focal length is 31mm and the effective F# is 0.8. The outer lens is germanium with a diamond like coating for durability. The lens is designed for diamond turning with commercial production tolerances. A fixed focus was not possible with the short depth of field caused by the low F# required to ensure sensitivity with an uncooled FPA. The mechanized focus automatically corrects for temperature induced focus shifts and reestablishes best focus when the distance between the observer and object changes shutter is included which is automatically activated. It is usually used every few minutes to re-characterize the array eliminating nonuniformities and assuring 50 milliKelvin sensitivity. Lastly, the shutter is also used for built-in testing.

Attribute	*Value*
NEDT in nominal operation	<90 milliKelvin
NEDT with frame averaging	<50 milliKelvin
Frame Rate	30 Hz
Nominal Power	<10 watts
Weight	2 Kg
IFOV	1.64 milliradians
FOV (degrees)	30 Horizontal, 22.5 vertical
FPA	320 by 240 Microbolometer
Bandpass	7 to 14 microns
MTBF	>15,000 hours

Table 2. Sensor Parameters

3.2 ERGONOMICS OF HELMET MOUNTING

Even though there are a number of critical requirements for a helmet mounted IR sensor and display, the most important helmet system requirement is the ergonomic one. Weight and balance are critical considerations for both comfort and safety. Placement of the components to minimize the off center moment and moment of inertia of the helmet sensor and display system on the operator's head is critical. The balance problem has additional complications in that the operator would like to have balance when walking as well as while looking down at a 50 to 60 degree angle. The design goal was to keep the moment under 90 Newton-cms. The final ergonomic concern is the ability to mount and position the hardware on the helmet, adjusting the display in front of the eye and boresighting the IR camera scene to the view through the display beamsplitter.

The helmet system must be rugged. It must survive being hit by tree limbs and bumping into equipment when worn, and withstand being dropped or bumped against hard objects when being set down after use, or even being kicked when sitting on the ground. Meeting these requirements is often not compatible with a lightweight low cost design, so a balance was struck. The helmetcam is designed to survive a 40g shock and 2g vibration. A unique attachment is implemented which is flexible enough to adjust for multiple helmet sizes and attach to different helmets without modifications. figures 3 shows the general architecture and mounting of the hardware on a SWAT type of helmet.

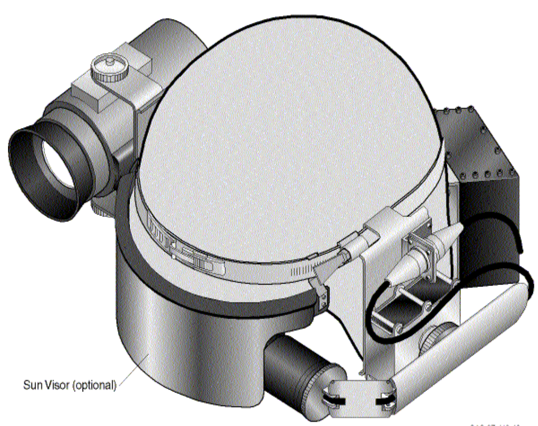

Figure 3. Helmetcam Attached to a Helmet.

3.3 PERFORMANCE

The deliveries of this first-version helmetcam were in 1997 and have constantly achieved NEDTs of less than 40 milliKelvin (measured with a 300 K blackbody and at 30 Hz with a recursive filter) with a standard deviation of approximately 6 mK. The average NEDT without a recursive filter was near 60 mK. The UFPAs have less than 1% of the pixels inoperable and no dead rows or columns in the center portion of the array. Recent advances in sensitivity and cosmetics of UFPAs result in improved performance. Figures 4 and 5 illustrate the imagery from delivered helmetcams. Note the reflections from people's heads in the conference table and thermal hand spots on the wall, behind the heads.

Generally, the UFPA stability is good. The UFPAs do not require uniformity correction often and at lfuture versions of the helmetcam may not require the non-uniformity correction paddle. They can operate for hours in an office or lab and still produce good images. The main cause for a non-uniformity correction seems to be change in environmental conditions.

The helmetcams have been consuming less than 9 watts, excluding power supply. They have been tested from –49 to +80 degrees C and operated throughout this range with reduced performance only at the high temperature end. The hardware has survived in excess of the 40g Shock and 2g vibration. The displays are bright and easily readable in the daytime and can be aligned to give a 1:1 overlay with the IR scene and the visible scene.

Figure 4. Helmetcam Image of Buried Object

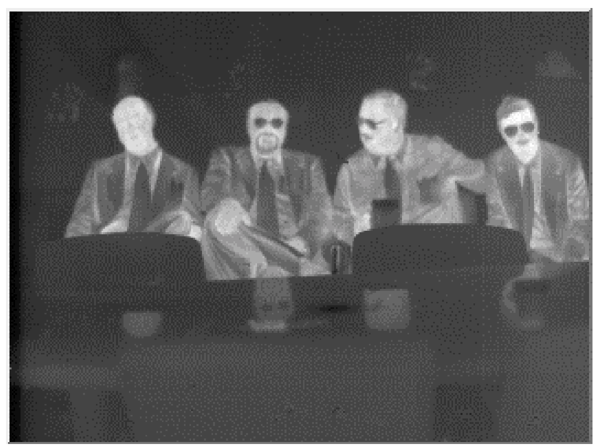

Figure 5. Helmetcam Image of People

4.0 SMALLER VERSIONS

Two other versions of infrared helmetcams were developed in 1998, each based on microbolometer UFPAs. The one pictured in figures 6 and 7 resulted from additional ergonomic trades. The ergonomic concerns for ease of use were traded against head-mounted weight and inertia. Internal mechanisms were removed to reduce weight, so this version requires manual focus and manual uniformity correction. Additionally, by exploiting UFPA improvements sensitivity can be approximately maintained with smaller optics. This version employs smaller optics at F#1.3, but has the same display and electronics. These helmetcams averaged under 60 mK NEDT and the sensor head weighed approximately 500 grams.

Figures 6 and 7. Small Militarized Version Provides Durability and Excellent Sensitivity

Figure 8. FireFLIR™, A One-Piece Visor IR Viewer For Firemen

Another version, specifically designed for firefighters has also been developed (figure 8). This low-cost version is a self-contained unit which quickly and easily clips to the lower portion of a US fire-fighting helmet with no external cables or components. Moreover, it attaches and provides a 1:1 magnification while wearing a self-contained breathing apparatus. Drawing its heritage from the militarized units, this version is lightweight, rugged (but not Mil-spec) and provides imagery comparable to B&W television. One special challenge in the design is the high temperature operation, where the exterior can be exposed to temperatures of several hundred degrees C (for a short time). FireFLIR™ provides consistently high definition imagery and optimal functionality for the firefighter. FireFLIR™ allows firefighters to see better and work faster providing a safer working environment, and more importantly, with additional lives and property saved.

5.0 CONCLUSION

Three rugged infrared helmetcams have been described which provide ergonomic infrared vision to the user. Excellent imagery with NEDTs well under 100 milliKelvin are possible using microbolometer arrays. By mounting the device on the head and close to the eyes, a natural perspective is presented to the user with minimum parallax. Such a sensor has broad applications in military, paramilitary, industrial and eventually (when price permits) commercial markets.